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Bicycle Facilities and the Uptake of Air Pollution by Active Travelers

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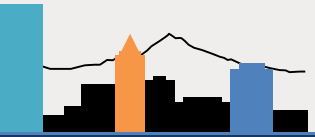


Bicycle Facilities and the Uptake of Air Pollution by Active Travelers

RESEARCH TEAM

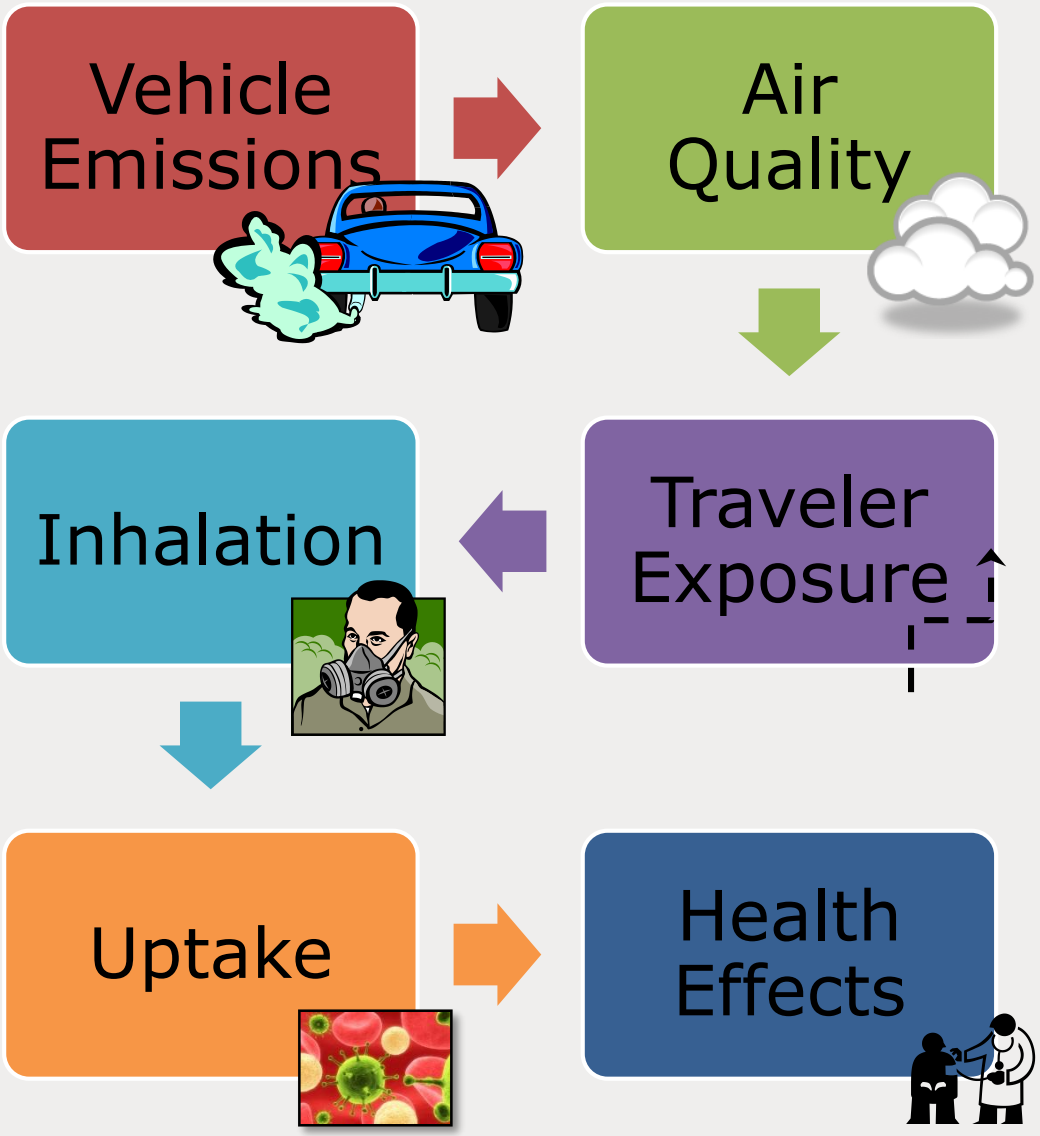
Alex Bigazzi, Ph.D. Candidate
Miguel Figliozzi, Assoc. Prof.
Jim Pankow, Prof.
Wentai Luo, Senior Res. Assoc.
Lorne Isabelle, Senior Res. Assoc.

Outline

1. Goals
2. Data Collection
3. Intake/Uptake
4. Modeling Results
5. Conclusions
6. Next Steps

Framework

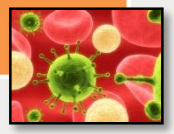
Adapted from Ott, Stieneman & Wallace, 2007



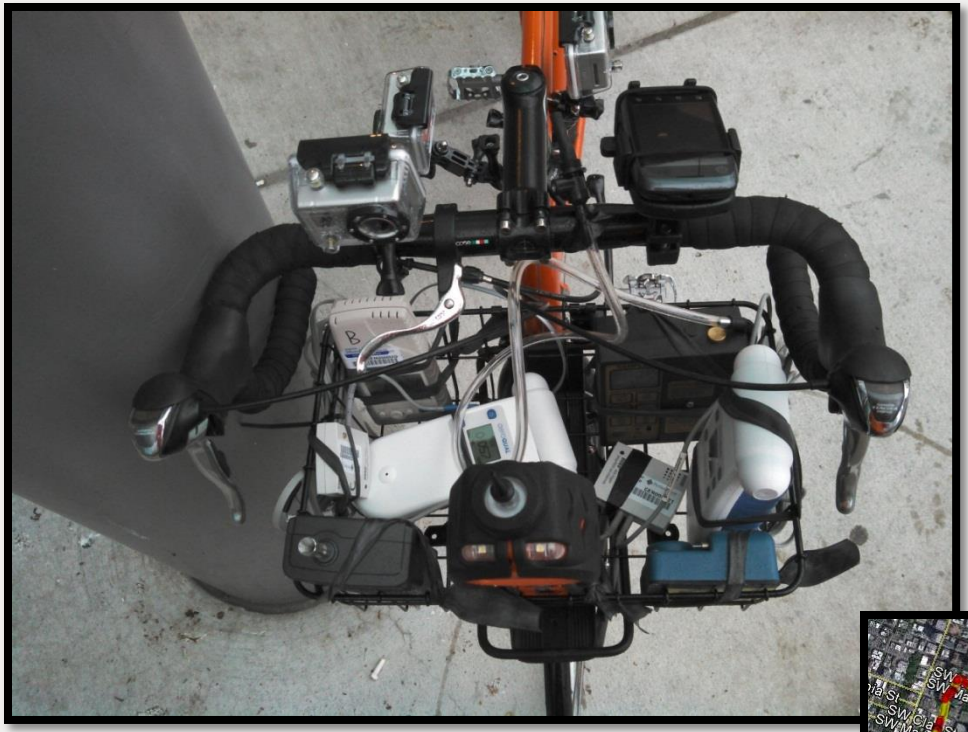
Traveler Exposure

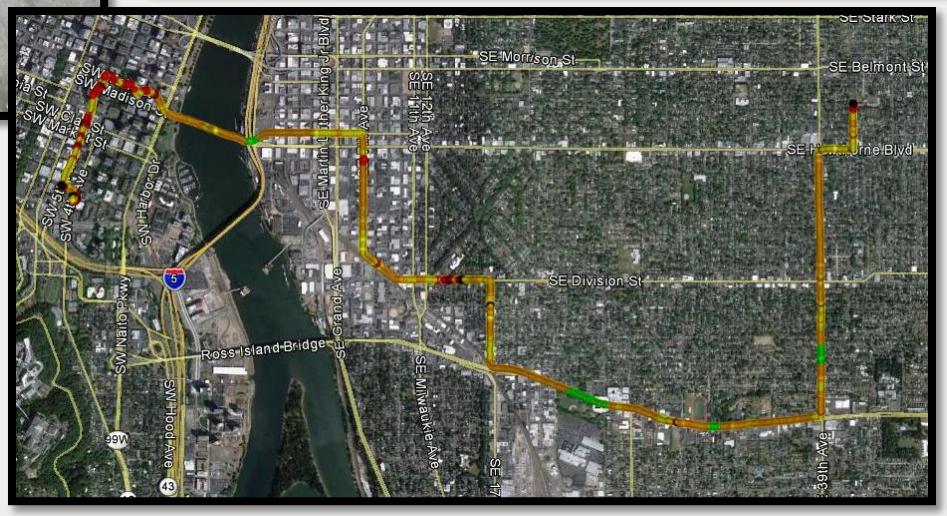
Inhalation

Uptake



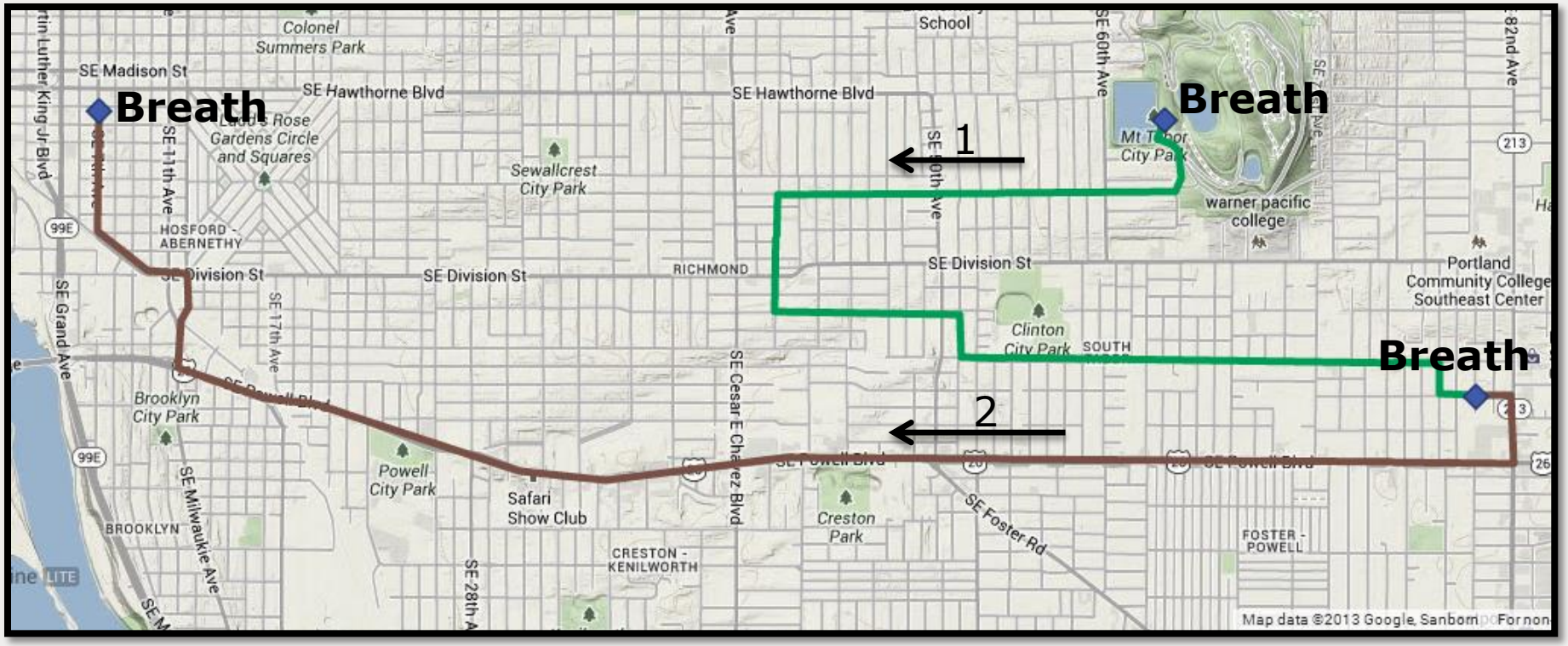
Data Collection





- 75 breath VOC samples
- 13 days
- 3 subjects
- 123 compounds

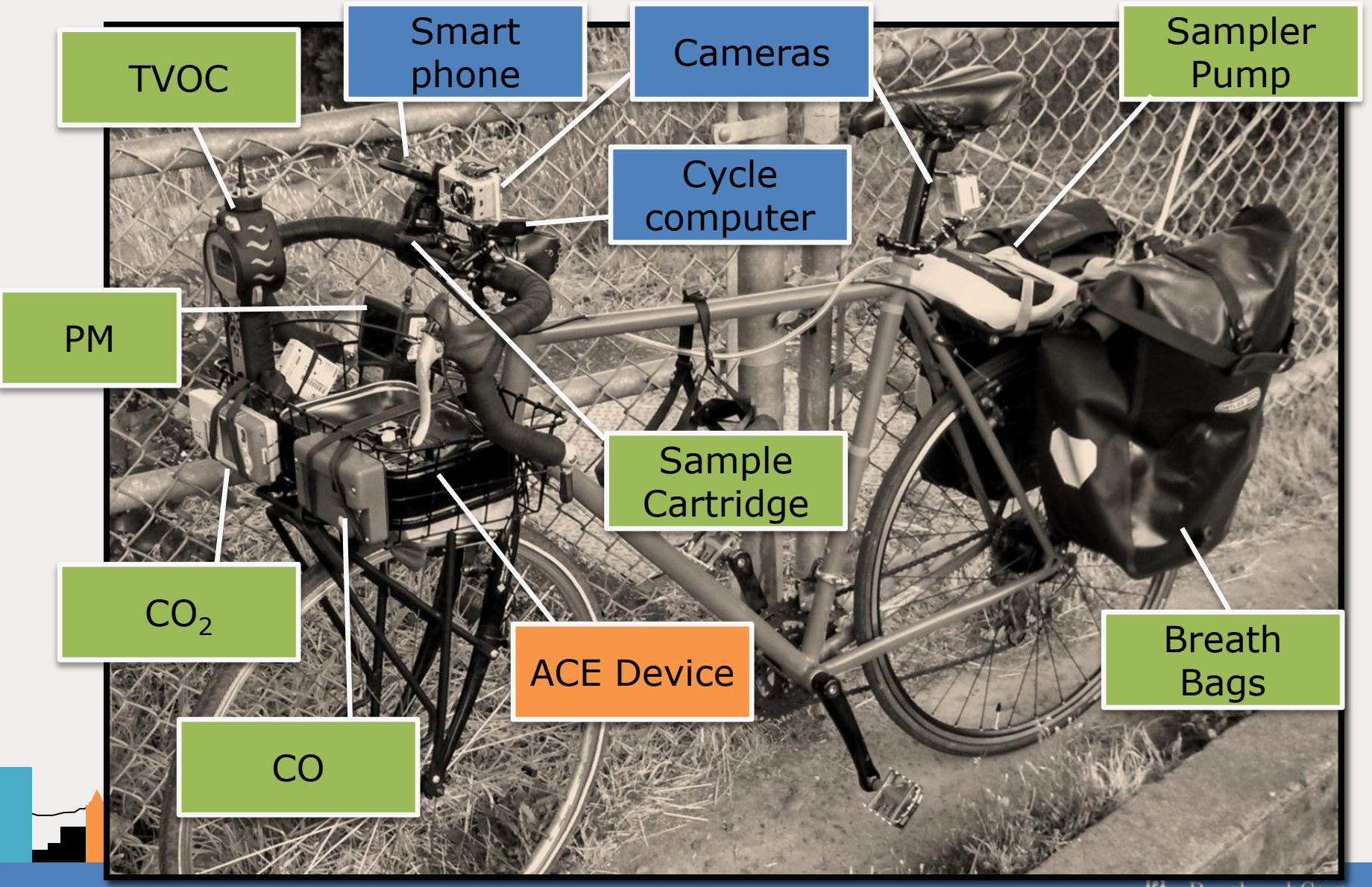
On-Road Sampling Example



Paired subjects; ambient & breath VOC

(20-30 minutes, 3-5 miles)

Sampling Equipment

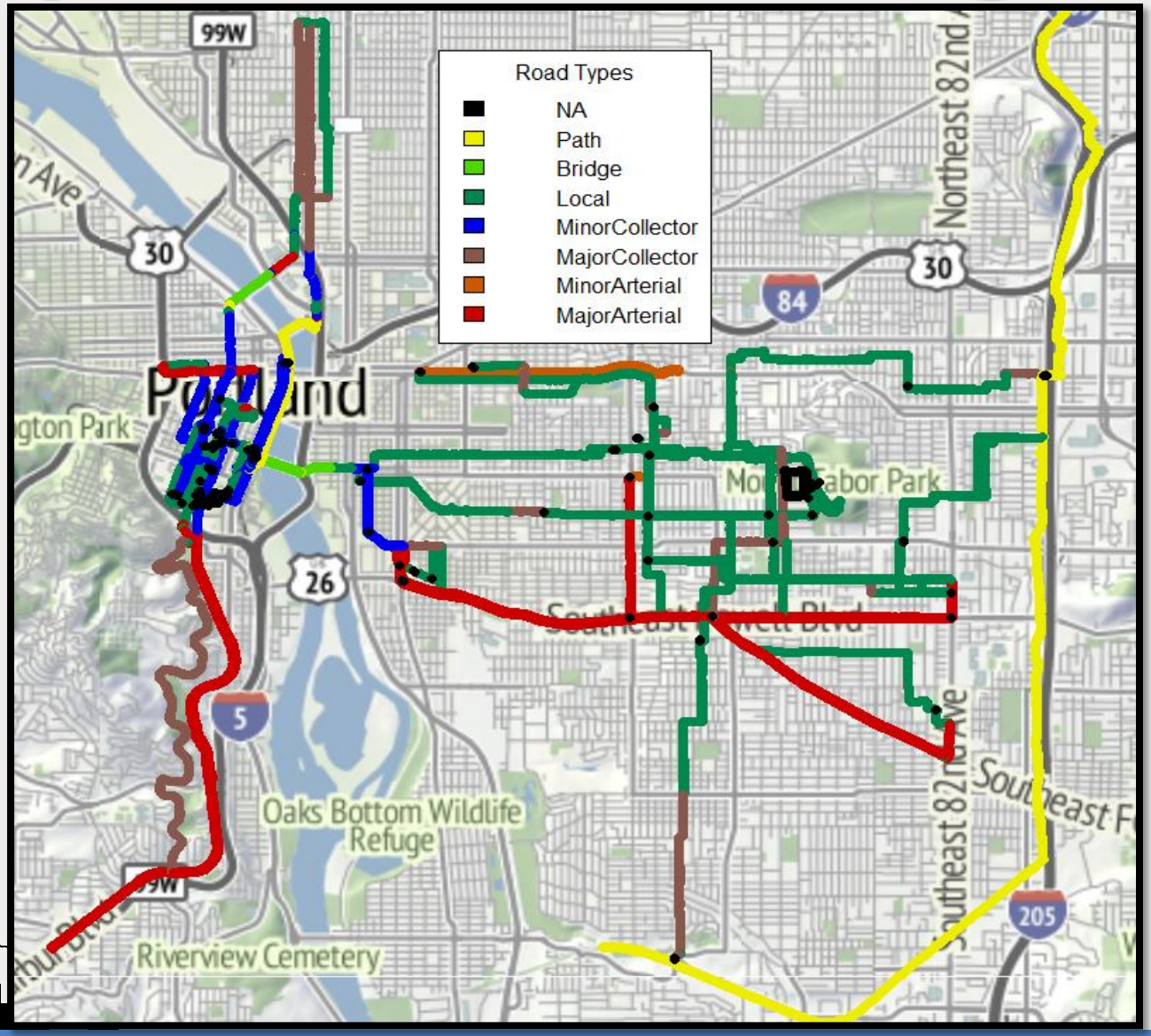


Breath Sampling

- Developed as medical screening
- End-tidal breath good proxy for blood concentrations
  - Low water-solubility VOC
  - Hydrocarbons like benzene, toluene,…
- Requires *very precise* instrumentation
- New standard for analysis with GC/MS

On-Road Sampling

Exposure Data coverage

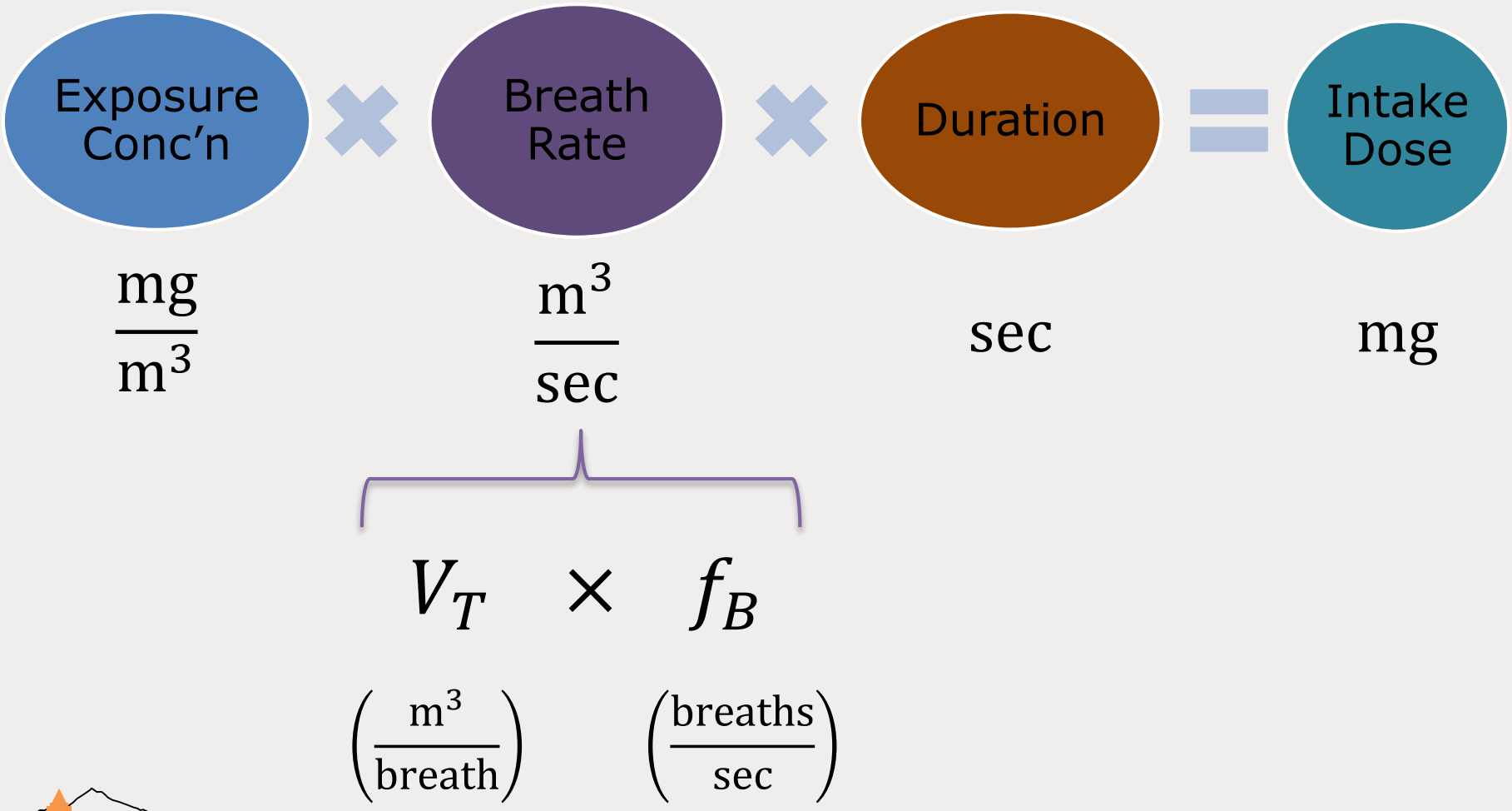


~40 hours of data over 13 days

- GPS and sensor data 1 second resolution

- Breath & ambient samples 30 minutes

Inhalation


Exposure Conc'n
Breath Rate
Duration
Intake Dose
$\frac{\text{mg}}{\text{m}^3}$
$\frac{\text{m}^3}{\text{sec}}$
sec
mg
$V_T \times f_B$
$\left(\frac{\text{m}^3}{\text{breath}}\right)$
$\left(\frac{\text{breaths}}{\text{sec}}\right)$

Bicyclists' Exertion

- External work
  - Speed & acceleration
  - Weight & slope
  - Wind & drag
  - Rolling resistance (tires, road)
- Personal factors (minor effects)
  - Basal metabolic rate
  - Fitness (exercise response)

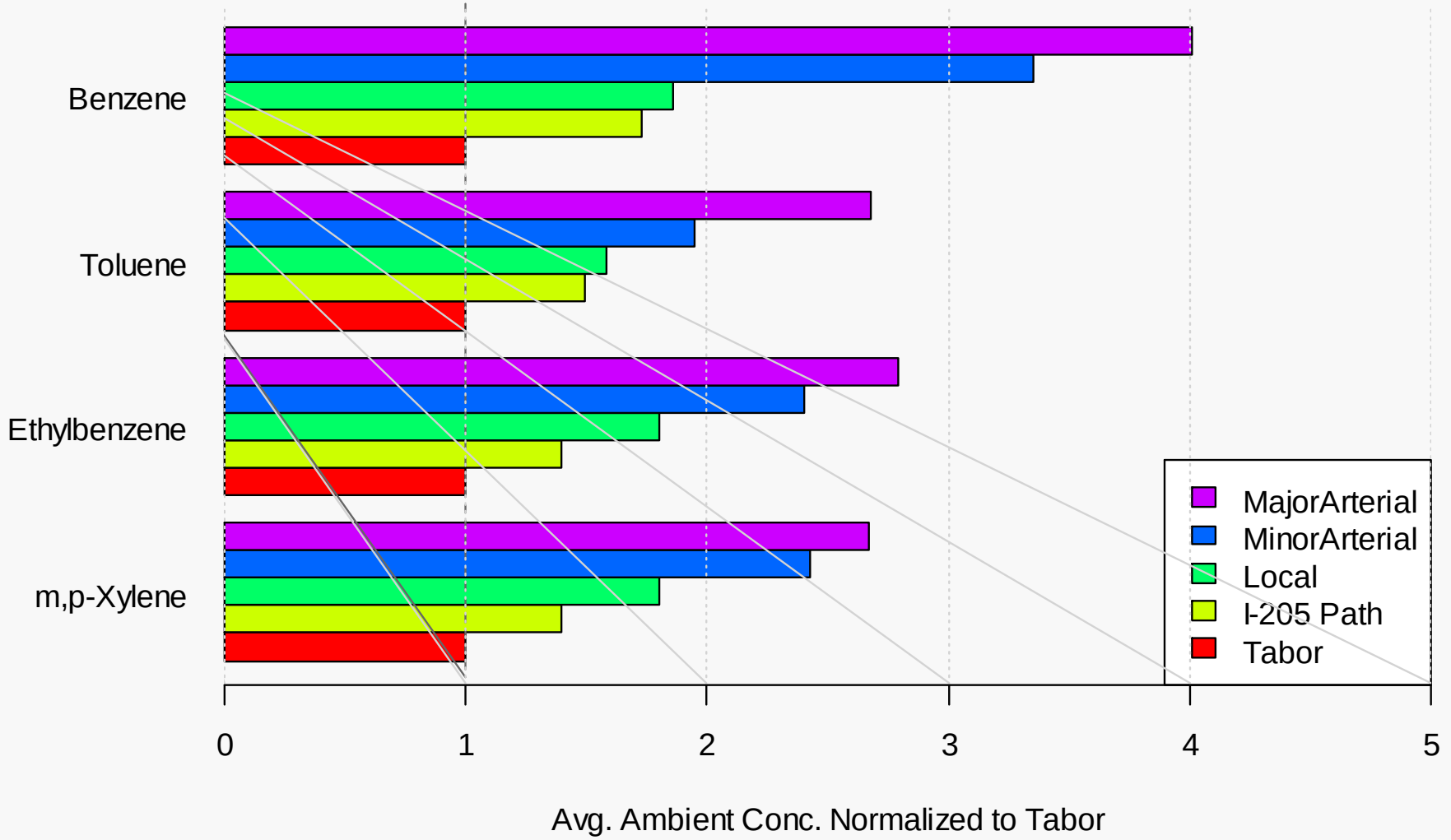
Bicyclist Uptake Studies

- Blood/urine samples (x1)
  - Metabolites of BTEX compounds (VOC)
  - Urban bikers > rural bikers
- Induced sputum samples (x1)
  - Lung-deposited black carbon
  - Bicyclists > transit riders
- Modeled uptake (x3)
  - Doses increases with exertion

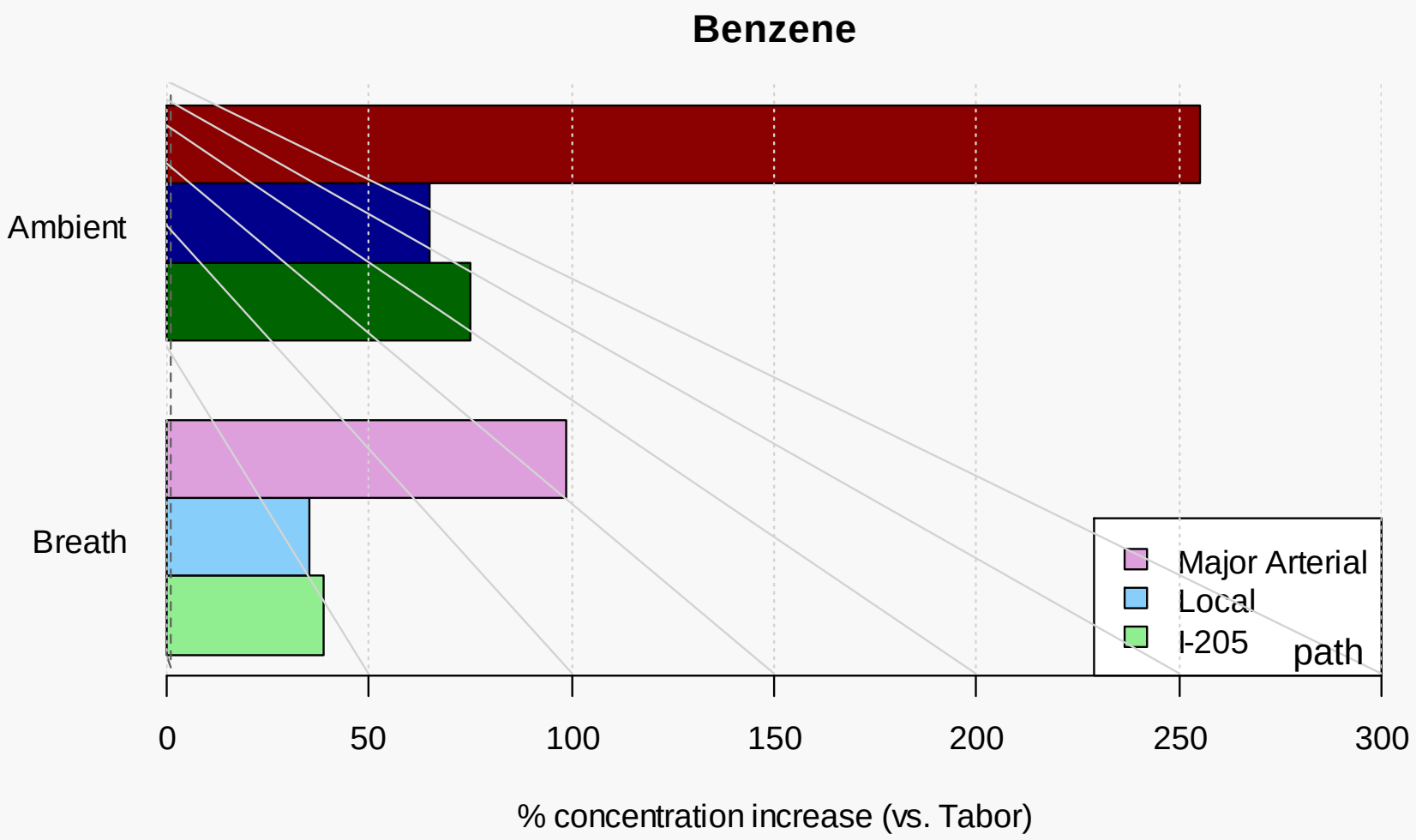
PSU Uptake Research

- New approach
- High-resolution intake/uptake measurement
- Breath sampling in bags

Some Exposure Results



Results Ambient & Breath



Regression - SURE Models

- Each of the select compounds is its own equation (same specification)
- Error correlations across equations for each observation are allowed
- Advantage: better use of the available information

Regression - SURE Models

Dep. Variables: breath/ambient concentrations

1. Benzene
2. Toluene
3. Ethylbenzene
4. m,p-Xylene
5. o-Xylene
6. 1,3,5-Trimethylbenzene
7. 2-Ethyltoluene
8. 1,2,4-Trimethylbenzene
9. 1,2,3-Trimethylbenzene

Breath concentrations

$$C_{breath} = \beta_0 + \beta_1 C_{ambient} + \beta_2 C_{preAmbient} + \beta_3 \frac{C_{preBreath}}{C_{preAmbient}}$$

$$(+) \qquad (+) \qquad (+)$$

- "History" impacts are significant
- Ambient coefficient 1.5 to 2.5 times bigger than preAmbient

$$\beta_1 > \beta_2$$

Change of Breath concentrations

$$\Delta C_{breath} = \beta_0 + \beta_1 \Delta C_{ambient} + \beta_2 \frac{C_{preBreath}}{C_{preAmbient}} + \beta_3 TVOC_{CV}$$

(+) (-) (-)

- "History" impacts are still significant
- Rate of change negatively affected by high *relative* breath concentrations

- High variability in $TVOC_{CV}$ reduces breath concentrations

Clearance impacts?
Policy/design implications?

Breath/Ambient concentration as a function of Road Type

$$C_{breath} = \beta_0 + \beta_1 \, \mathbf{RoadType}$$

$$C_{ambient} = \beta_0 + \beta_1 \, \mathbf{RoadType}$$

- Road type is a dummy variable (5 different types of roads, Tabor the reference)
- Road type is a much better predictor of ambient than breath concentrations
- Arterials have 1.5 to 2.5 higher ambient concentrations than local/bike paths
- Major arterials 25% more than minor
- Non-linear AADT impacts?

Wrapping up

- The method works: exposure predicts breath concentrations
  - Breath elasticity to exposure: 0.3-0.5
- Significant history effects
- Significant road-type effects
- Minimal subject-specific effects

Future Work

We have a novel data set of direct uptake measurements

- Much more analysis work to do!

1. AADT impacts
2. Policy and Design Implications
3. Bicycle network/facility design guidance for pollution dose impacts
4. Extend to pedestrians

Thank you!

- Bigazzi, A. and M. Figliozzi, "Review of Urban Bicyclists' Intake and Uptake of Traffic-Related Air Pollution." *Transport Reviews*, Forthcoming 2014.
- Bigazzi, A., W. Luo, M. Figliozzi, J. Pankow, and L. Isabelle, "Measuring urban bicyclists' uptake of traffic-related volatile organic compounds using ambient and breath concentrations." 93rd Annual Meeting of the Transportation Research Board, Washington D.C., January 2014.

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http://web.cecs.pdx.edu/~maf/

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